ESTABLISHING A GEODETIC CONTROL NETWORK TO SERVE AS PHOTOGRAMMETRIC CONTROL FOR A COUNTYWIDE GIS

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BIOGRAPHICAL SKETCH

As manager of geodetic services for Woolpert Geographic Information Services Division, Mr. Stanoikovich is responsible for overseeing daily geodetic operations. He specializes in projects for infrastructure applications, projects that require significant ground control, and other field surveying services such as GPS satellite surveying. He ensures that projects are performed according to client requirements and completed within the specified schedule and budget. His experience includes Global Positioning System (GPS) surveys; photogrammetric control; and utility, boundary, topographic, and geodetic ground control surveys.

Mr. Stanoikovich has performed geodetic services for the City of Cincinnati, Ohio; the Cincinnati Area Geographic Information System (CAGIS); Delaware County, Ohio; Fairfield County, Ohio; Butler County, Ohio; Lorain County, Ohio; Ottawa County, Ohio; Geauga County, Ohio; Sandusky County, Ohio; Bartholomew County, Indiana; and other clients in the United States and South America.

Woolpert is a multidisciplinary firm with capabilities in engineering, photogrammetry, architecture, planning, and landscape architecture. These capabilities enable Woolpert to provide Geographic Information Services, Public Works and Infrastructure Services, Aviation Services, and Environmental Services. The firm, which has 13 offices in nine states and employs more than 500 people, has been in business since 1911 and is based in Dayton, Ohio.

ABSTRACT

The surveying industry has seen many changes in the past decade. The total station was a great addition to the profession, along with sophisticated data collectors and unmanned instruments that use radio-based tracking and servo motors. But perhaps the most important addition to the geodetic surveying community was the introduction of the Navstar Global Positioning System (GPS), allowing the surveying industry to establish affordable, high-accuracy geodetic control. These new technological developments, along with the skills of trained professionals, will aid in the establishment of a geodetic/photogrammetric control network for cities, states, and counties that plan to implement a Geographic Information System (GIS) or some other type of mapping project.

INTRODUCTION

With the term "GIS" becoming as common among government agencies as elections, the need for knowledge and understanding of the GIS concept becomes more important. "You get what you put into it" holds true in life as well as in a GIS of any type.

Because so many agencies are getting involved with GIS technology, it is important to understand the vital role played by a control network in planning and creating a GIS. This paper examines three categories of control networks by evaluating their relative costs, accuracies, and recommended applications. It also provides step-by-step guidelines for planning a GPS control network.

THREE TYPES OF NETWORKS

The foundation of the GIS is its geodetic control base. This framework of geodetic positions establishes the accuracy to which all other data is related.

For a control network that serves as the basis of a GIS, the old adage about a chain and its weakest link is very appropriate: The GIS itself can only be as accurate as its control network. No amount of software and hardware enhancement can compensate for control that is not accurate enough for the required uses.

There are three types of GPS control networks: surveying/engineering, photogrammetric, and dual-purpose.

Surveying/Engineering GPS Control Network

This network consists of a series of stations that are usually laid out in a grid-type pattern (however, a rectangular grid is not necessary). Many city and county agencies choose this method, using sectionalized land corners as the station grid. This method has been used by many counties throughout the U.S. and has been proven as a strong reference base to support a GIS. Franklin County, Ohio, is one of the best examples of this type of network in the state of Ohio.

However, one of the drawbacks of this system is that it is expensive to create. Section corners must be located or re-established, permanent monuments must be placed at the location, and, if the corner falls in a roadway or a developed area, some type of monument box and/or protective feature must be added to ensure its stability. Also, it is important to consider the safety issues involved in trying to occupy stations situated in the roadway. This applies both to GPS crews establishing the position of the station and to surveyors using the station for other surveying purposes.

Another network that falls in this category is one that consists of stations placed either in municipal parks and recreation areas or on the grounds of community school board property. This type of geodetic station layout has been used quite effectively by the City of Cincinnati, Ohio. This method has several advantages, one of which is the unlikelihood of disturbance to the station due to construction. Another is that the areas are easily accessible and—depending on the neighborhood—are usually safe to occupy even during nighttime observation sessions. This network is considerably less expensive to set up than the first type of network, but the GPS portion of the project is equivalent.

Following the Federal Geodetic Control Committee's *Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques* (Version 5.0 or the latest version), accuracy standards for this type of network should not be less than 1 part per 100,000.

Photogrammetric Control Network

When GPS control is needed to support a digital mapping project, orthophotography, or both, control location is determined by the needs of the photogrammetrist. Most photogrammetric firms that perform fully analytic triangulation use a perimeter control pattern.

This approach allows the photogrammetrist to control the mapping project from high-altitude photography, which minimizes the amount of horizontal and vertical control needed. This yields an acceptable fully analytic triangulation result without deteriorating the accuracy of the project. Some of the points are positioned along the sides of the project (parallel to the flight line of the aircraft). The majority of the stations, however, are placed along the sides of the project that contain the beginning and end of the flight lines.

This layout offers the lowest-cost alternative for obtaining photogrammetric control. However, it does not meet the requirements of a strong geodetic control foundation to support and maintain a GIS in the years ahead. Another drawback to this network is that the accuracy needed to support the mapping portion of the GIS is not sufficient to support the surveying/engineering demands of a GIS. For these reasons we will discuss the third—and perhaps the most versatile—type of control network.

Dual-Purpose Geodetic/Photogrammetric Control Network

This type of control network supports a variety of users. One of its greatest assets is that it meets both the photogrammetric needs of a GIS and the higher-accuracy control needs of the surveying/engineering community. This is especially important because the dual-purpose type of network can be significantly less expensive than the surveying/engineering type, and costs can often be distributed among the participants in a GIS project.

Accuracy requirements for this type of network should not be less than 1 part per 100,000 (this accuracy can be achieved easily using GPS techniques).

The network pattern is laid out in much the same manner as the photogrammetric control network. However, in the dual-purpose network, inner control is added as well as possible station pairs or station azimuths. If lower-altitude photography is needed for urban/suburban areas, additional control should be laid out in these areas. This will meet the needs of the photogrammetrist while adding to the density of the control pattern. If only one scale of photography is designated, it is still advantageous to place inner network control near areas of expansion and growth as well as small rural communities while still maintaining some type of rectangular grid pattern.

Once the network pattern has been established, further densification can be made either through terrestrial techniques or through GPS. But whatever method of densification is chosen, this method accommodates both the GIS of today and the GIS of tomorrow.

In fact, it is very important to plan for the future needs of a GIS. Continuous updates will be needed in areas of expansion and growth. These updates will require new photography, geodetic control, and mapping. Previously established control stations can be targeted to help support the analytic triangulation phase of the update process.

In the GIS of the future, all boundary surveys, construction projects, and so on, should relate to the coordinate system of the geodetic control network. This process has the benefit of adding data that is far more accurate than the original digitized land information data.

Through methods that use the dual-purpose control network, the accuracy of the overall GIS can be efficiently and cost-effectively enhanced. This means that the dual-purpose network is an investment in the future, and represents the best value for the GPS dollar spent.

PLANNING A CONTROL NETWORK

There are several questions to address when planning a control network:

1. **What are the intended uses or applications of the network?**

   This step may require meeting with all potential users to determine their level of interest, their requirements, and their existing information base. It may also be the ideal time to discuss the potential for budgetary commitment.

2. **What are the accuracy requirements of the network?**

   The accuracy used will probably be influenced by factors that include planned uses and available budget.

   The Federal Geodetic Control Committee (FGCC) defines three broad categories of accuracy for geodetic control networks. The table on page 5 provides a brief overview of these categories and shows how they relate to the three types of networks described earlier.

   For more detailed specifications on these types of control, see the FGCC publication *Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques*, which was used as a resource for the information presented here.

With GPS capabilities, no control should be established with accuracies less than 1 part per 50,000. In fact, it is recommended to require accuracies of not less than 1 part per 100,000. In most cases, the cost difference between the two accuracy levels is minimal.

Description	**Minimum Accuracy**	**Recommended Uses**	**Type of Control Network**
First-order horizontal control network	1 part per 100,000 (1:100,000)	Called the Primary Horizontal Control, this is the framework for the National Horizontal Control Network. It is recommended for metropolitan area surveys and scientific studies.	• Surveying/ Engineering GPS • Dual-Purpose Geodetic/ Photogram-metric
Second-order horizontal control network	• Class I: 1 part per 50,000 (1:50,000) • Class II: 1 part per 20,000 (1:20,000)	• Class I, Secondary Horizontal Control, is an area control that strengthens the National Network. It is recommended for subsidiary metropolitan control. • Class II, Supplemental Horizontal Control, is used to establish area control that contributes to but is supplemental to the National Network.	Photogrammetric
Third-order horizontal control network	• Class I: 1 part per 10,000 (1:10,000) • Class II: 1 part per 5,000 (1:5,000)	Called Local Horizontal Control, this pertains to general control surveys referenced in the National Network. It is recommended for local control surveys.	Low-end Photogrammetric

3. **What is the available budget for the project?**

   Using the budget information gathered from the users identified in answer to question 1, determine the available budget for the project.

4. **Which of the three networks will be established?**

   Based on information about applications, accuracy requirements, and available budget, the next step is to choose the type of network. Taking the time to answer the first three questions carefully should make the choice of network fairly simple and straightforward.

5. **Should the network data be included in the National Geodetic Reference System (called "blue-booking")?**

   This question also concerns the issue of accuracy. It is recommended that the initial network information be submitted for inclusion into the National Geodetic Reference System (blue-booking), but only if the survey meets the above accuracies. One of the many advantages to blue-booking the control data is this: Once the data has been accepted by the National Geodetic Survey (NGS), it is maintained, updated, and published by the NGS and is not affected by political restructuring in the years to follow.

6. **What are the forecasted costs of the project, and how can the costs be minimized?**

   Now that many facets of the project have been decided, it is possible to forecast the project budget. For this step, it is important to understand that costs can vary greatly due to the demands and constraints of the project, and no hard-and-fast price per station can be set for any one project.

   In these days of tighter budgets, cost control is critical. Although final project costs vary considerably, there are many ways to minimize costs. Perhaps the most efficient method of cutting the final cost of a project is for the agency itself to complete the station locations, reconnaissance, visibility studies, monumenting, and referencing. When these tasks are performed by the agency, the savings can reduce the final project cost by as much as 50 percent.

7. **Who can provide assistance in planning the project?**

   Two valuable sources of assistance are contractors and the NGS itself. Many contractors offer geodetic services, and most of them are glad to assist in planning a geodetic control network that will meet the agency's needs.

   For preliminary ideas and information, contact the NGS advisor in your state. (If one is not available, contact the NGS headquarters in Rockville, Maryland.) An NGS advisor can provide valuable information about similar projects taking place in your state. Contact the agencies identified for ideas that will help you determine your final plan.

CONCLUSION

The three types of GPS control networks discussed provide different levels of accuracy, serve different types of applications, and require different budget commitments. At the high end of the scale is the surveying/engineering network, which is expensive but extremely accurate. It serves as a strong reference base for a GIS and future surveying and engineering needs. At the other end of the spectrum is the photogrammetric control network, which represents a low-cost approach; however, the accuracy is insufficient for many uses of a GIS. A good compromise is the dual-purpose network, which provides sufficient accuracy for surveying/engineering applications at a lower cost.

Careful planning is the key to choosing the right type of network. Answering the questions about applications, accuracy requirements, and potential budget should guide the choice of network. Then with the type of network decided, answers to questions about blue-booking, projected costs, and sources of planning assistance can help ensure the success of the overall project.

Finally, when initiating a countywide or citywide control network, the agency should remember that the actual GPS portion of the project is only part of the total network cost. When implemented properly, the network will meet the needs of all area GIS users well into the 21st century.

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RESOURCES FOR ADDITIONAL INFORMATION

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